two illustrations. The printing, both from wet-plate negatives and from paper negatives, is done in a large pneumatic printing frame. This is designed expressly for the work, and so far as the locking and attaching of the rubber cloth is concerned, is the only one of its kind extant. Although it requires most careful locking to be effective, Mr. Carkhuff devised a means whereby the locking and unlocking of the back of the frame could be accomplished in one movement of a hand lever, instead of the eight separate movements formerly required. An air-pump exhausts the air from this frame, applying thousands of pounds of atmospheric pressure to the negative and paper, and thus insuring an absolutely even contact between them. The back of the frame is counter-balanced, to avoid the needless exertion of strength in raising and lowering it. The frame stands in front of a shutter, behind which is a powerful electric light. This shutter is operated by a foot-lever, and for the average exposure is made to wink in about a half second. A specially-prepared developing paper is used, particularly adapted to printing in line, which is the bulk of the work done here.

The print is developed by hand and fixed in a large bath, which can be seen on the end of a big washing sink; this can be swung up out of the way when the latter is wanted for washing the print. The fixing solution collects in a partition at one end of the big tray, and remains there until the tray is lowered, when the solution resumes its former position. When the prints have been washed, they are dried in racks, consisting of spring rollers on which is wound cloth. Through the free end of this cloth, which ends in a turn-over, is thrust a stick. Uprights with serrated edges stand the proper distance from these rollers, and the stick is so fitted as to slip into these serrations. By this device an immense number of prints can be dried at once, and in a very small space, and when no prints are being dried, the cloth stretchers are out of the way. The uprights are movable, also, so that this entire space is available for other things when wanted. In the photograph showing the printing frame and its light, will be seen a large oak case. This case holds the various sizes and varieties of paper used. Each separate flat cupboard has a false bottom, which can be readily removed. When a fresh consignment of paper is received, this false bottom is taken out, loaded with the paper, and slid back into place. Any one compartment can be opened without exposing the others, and the paper is absolutely safe in them. By using a scheme of this kind, not only is a great saving effected in paper, but in the time required to handle it, and in space formerly occupied by the boxes in which the paper is packed. The ventilation scheme comprises electric fans so placed that they do not merely agitate the air, but actually carry it out at the top and draw fresh air in from out-of-doors.

In the smaller dark-rooms and velox printing rooms, the small work is done. The Geological Survey takes thousands of pictures in the field every year, and these are all developed and printed here. There are a number of small dark-rooms, each a model in its way, and all absolutely clean. The keynote of the whole establishment is absolute cleanliness, and the photographic visitor at once remarks the absence of paper on the floor, junk in the corners, and useless bottles and chemicals on the shelves.

Eleven men are regularly employed in this establishment, and with the great number of labor-saving devices, they easily do the work of triple their number under ordinary circumstances. It is necessary that they should, for the twenty rooms of the laboratory will not stretch, and the work must be done by the force which can be comfortably put in them. Hence every improvement which is made must be either to save space, time, or money.

It is by no means possible to cover such an establishment fully in a short article. There is, for instance, the microscopy room, where the rock section photomicrographs are made and nothing else. Then there is the fossil laboratory, where these interesting objects are photographed with special apparatus designed for that work.

The Pleiades Showing Nebulosity.

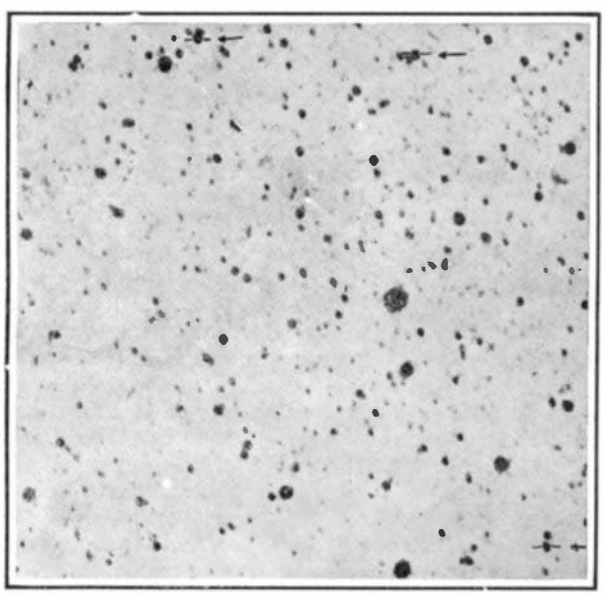


Fig. 1.—Showing About 0.001 of a Region Near the Center of Small Magellanic Cloud.

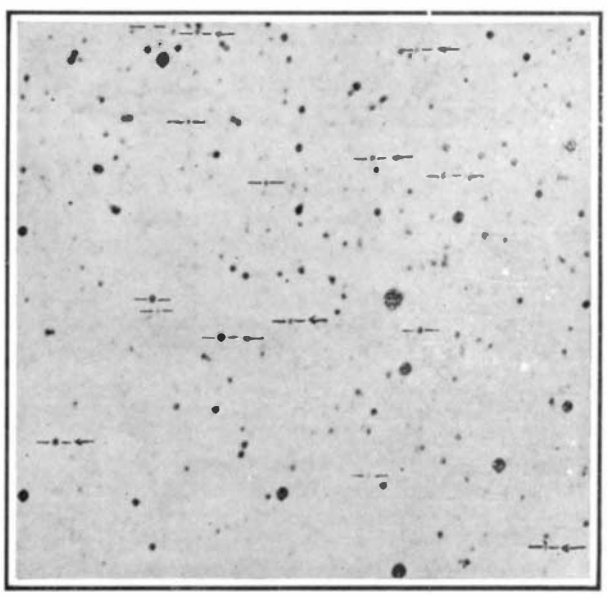


Fig. 2.—Same Region as Fig. 1, Showing Changes in the Stars.

SOME UNUSUAL DISCOVERIES OF VARIABLE STARS AT HARVARD OBSERVATORY.

BY G. A. THOMPSON.

Although it has long been recognized by astronomers that an investigation of the nebulous regions of the sky would yield much useful information, owing to the great amount of work already in progress at Harvard Observatory, a special detailed study of such regions for the detection of variable stars was begun there only during the past year. Except the great nebula of Orion, which has been the subject of careful study with observers for years, and the large and small Magellanic clouds, almost nothing was known of existing conditions in such regions prior to this beginning. The number of known variables eighteen months ago was about 1,500, of which about 970 were found at Harvard after 1890. About 200 of these were discovered by Mrs. W. P. Fleming, curator of astronomical photographs, from photographs of their spectra; about 500 others by Prof. Solon I. Bailey of the Arequipa station of Harvard Observatory, through examinations of star clusters.

Prof. Edward C. Pickering, director of Harvard Observatory, already and for a long time deeply interested in this subject and aware that an unusual harvest of scientific fact might be gathered from a thorough and detailed study of variable stars, which he believed would be found in large numbers in the nebulous regions of the sky, was most anxious to begin such an investigation at Harvard without delay. A grant made by the Carnegie Institution for 1903 permitted a large amount of work of this kind to be undertaken at Cambridge, and furnished a corps of eight observers for the study of the Harvard photographs. But the failure to continue this grant for 1904 rendered it necessary to disband this corps, and since December, 1903, similar work has been carried on at the expense of the observatory by one observer only—Miss Henrietta S. Leavitt, who began her present investigations during the latter part of February, 1904.

In 1901 and again in 1903, Prof. Max Wolf, of Heidelberg, compared several of his photographs by means of stereo-comparators, the small stereoscopic instruments which have proved so important a factor in astronomical work, and of which we are likely to hear more and more in future astronomical investigations. Prof. Wolf thus found and announced 33 variables in the neighborhood of Orion. But until the present investigation at Harvard, they do not appear to have been confirmed by other observers. Some photographs of the nebula of Orion are contained in the Harvard collection, and a careful examination of them was made by Miss Leavitt early last year. Besides confirming 18 of Wolf's variables, she thus found 72 new ones. It is possible that many others will also be discovered in this region, when more photographs become available for comparison, as many of those found appear to remain at their minimum magnitude during a large part of the time. The plates for the examination were superposed successively upon a glass positive made from one of them, after the method

Orion, Showing the Great Nebula.

The Nebula in Carina.

followed in such investigations at Harvard. A curious fact regarding the variable stars in this region is that they are found within and following the denser distribution of the nebula.

In no respect have the results of photography been more striking than in the revelation of diffused nebulæ of vast extent, whose faintness renders them almost beyond the reach of visual observation. One of the most remarkable of these extends over many square degrees in the constellations of Scorpius and Ophiuchus. Like the nebula of Orion, it attaches itself to individual stars, the principal condensation being about the quadruple star η Ophiuchi. The region is marked by a noticeable absence of stars of the fainter magnitudes, and dark lanes can be traced in different directions for a considerable distance beyond the visible nebulosity. An examination of a part of this region has led to the discovery of seventy-two variable stars, besides the eight already known.

In the trifid nebula in Sagittarius, which is near the center of a large number of the photographs taken for the study of Phœbe, the ninth satellite of Saturn, discovered by Prof. William H. Pickering in 1899, a careful search for variables was made by Miss Leavitt during the latter part of 1904. Yet only sixteen were found. A little earlier in the year, however, in the course of an examination of this region, a very interesting variable of the Algol type was discovered. Over 300 plates were available for the study of the new object, on twenty-eight of which it is fainter than the normal brightness, magnitude 9.55. In three cases it appears faint on two plates taken during the same night, so that twenty-five different minima have been observed. The observations indicate that the period is about 3.45 days, with a range of about one magnitude. An interesting and unusual feature in the variation is found in the fact that a secondary minimum occurs between the primary minima, and is about three-tenths of a magnitude fainter than the normal brightness.

The most fruitful field, however, that has been examined is the small Magellanic cloud, where up to the present time 900 variable stars have been discovered and sixty-four others suspected of variability. In a circular issued by Harvard Observatory May 26, 1904, announcement was made of the discovery of fifty-seven new variable stars in this region. In order to provide material for the study of the light curves of these stars, sixteen excellent photographs, having exposures of from two to four hours, were taken last autumn at Arequipa, with the 24-inch Bruce telescope. These plates reached Cambridge in January of the present year, and an examination of them by Miss Leavitt led to the surprising discovery that hundreds of variable stars were present in this region, the small number found in her earlier examination being due to the unsatisfactory quality of many of the plates.

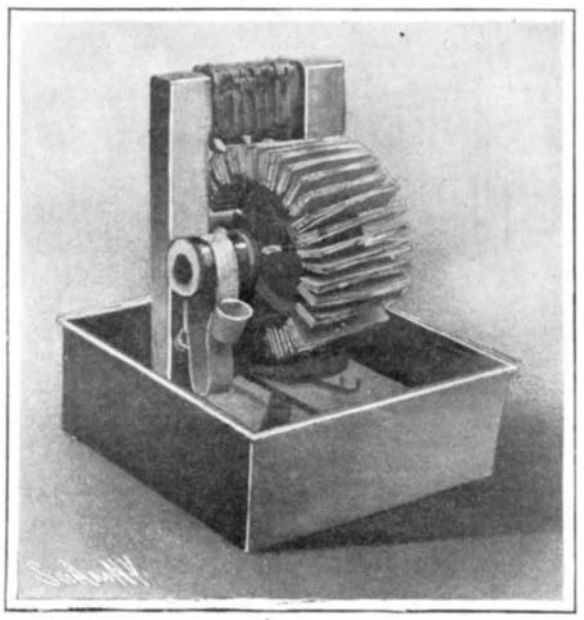
Nearly all the variables are found strictly within the limits of the cloud. Few have been found at a greater distance than a degree and a half from the center, excepting in the clusters 47 Tucanæ and N. G. C. 362. To study their distribution, the region of about six by seven degrees, covered by the plates, has been divided into squares which measure approximately half a degree on a side. The center adopted is not far from the center of the cloud, which extends diagonally in a direction from northeast to southwest. The limits of the region containing the variables are more sharply defined, and are closer to the central line of the most densely crowded portion on the preceding than on the following side.

Several examples of variability are shown in Figs. 1 and 2, which are enlarged six times from the original photographs, and cover about one-thousandth of the entire region. The area represented is 12 minutes square. Fig. 1 is an enlargement from Plate A3393, taken November 10, 1898, exposure 300 minutes, and Fig. 2 is from Plate A6981, taken September 30, 1904, exposure 240 minutes. All the variables in the region are marked on the latter, while on the former three stars are marked of which the changes are well seen on this pair of plates. There are many other regions of equal interest. No catalogue stars are contained in these regions, as even the brightest are too faint to appear in the Cape Photographic Durchmusterung. The number of stars shown in the photographs, in the central portion of the region, is about thirteen to a square minute of arc, or 46,800 to a square degree. It is estimated that the number of stars photographed in the small Magellanic cloud and adjacent clusters is about 280,000, of which 910, or one in 308, is variable.

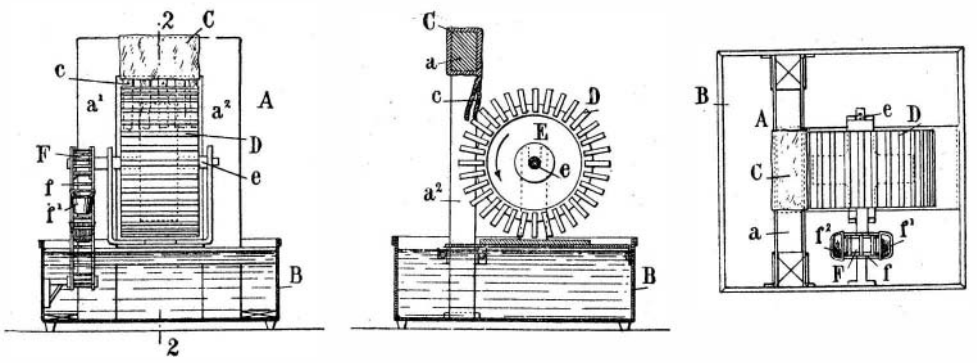
The results of this great scientific undertaking have been thus far very gratifying. In a little more than one year the number of known variables has been almost doubled, and a great deal of interesting and important information secured. One of the most interesting facts established is the great and often surprising dissimilarity of different nebulæ. In the beautiful cluster of the Pleiades, for instance, which is nebulous, and where one might expect to find an especially large number of such stars, no cases of variation have yet been found. In the nebula surrounding η Carinæ, considered by many the finest nebula in the sky after Orion, very few variable stars have been found. The large Magellanic cloud, also, similar in formation though it is to the small Magellanic cloud, seems to contain but few, if any, variables; out of 867 star images examined last year in the looped nebula, two were suspected of slight variability. The facts as they exist at present render such regions doubly interesting, since they illustrate how impossible it is to deduce any rule that will govern all nebulous regions alike. Even with regard to the type of variation found in the various nebulæ there is little similarity. Each nebula is a law unto itself.

The total number of variable stars that have been discovered by Miss Leavitt since she began her investigations in February, 1904, to the date of writing this paper is approximately 1,300. Yet the work is hardly more than begun. For the collection of photographs at Harvard includes nearly 200,000 plates, giving an exhaustive history of the sky during the past sixteen years, and of the more interesting regions since 1883; not only must the majority of these be carefully examined, but as new plates are constantly being taken at the Cambridge and Arequipa stations, fresh work is constantly being added. Moreover, it is possible that the large reflectors, now being mounted at Harvard and elsewhere, will make apparent new nebulæ too faint to be detected on present photographs, and that among the stars of the very faint magnitudes that will appear on these future plates will be found many cases of variation.

A discussion of this examination and of the work entailed by it would not be complete without some mention also of its effect upon another department of the research at Harvard. A complete bibliography of all the variable stars then known was begun there some years ago by Prof. W. M. Reed, now of Princeton. This work was resumed in September, 1900, and has since been continued by Miss Annie J. Cannon, so that there are now more than 35,000 cards. A minute record of every observation of each star in the series is thus kept, with the name of the observer, the observatory and instrument, as well as the technical description of the star, its position, period of variability and dates of maximum and minimum. Not merely, therefore, is the present study of nebulous regions adding a long list of variables to those already known, which in itself would be simply an interesting event in the course of scientific progress, but it will furnish an amount of detailed information concerning them, which will prove of inestimable value to astronomers and to others who are interested in the science.



A MOTOR DRIVEN BY CAPILLARY ATTRACTION.



END, SIDE, AND PLAN VIEWS OF THE CAPILLARY MOTOR.

THE CAPILLARY MOTOR.

BY DR. ALFRED GRADENWITZ.

A highly interesting application of capillarity for motive purposes has recently been patented by a French engineer, Mr. G. Leboyer, of Riom, Puy de Dôme.

Certain rocks, and especially those met with in volcanic countries, possess an exceptional power of capillary attraction, rendering them well adapted for the generation of small powers. A rotary apparatus utilizing this property is represented in the accompanying photograph, and shown diagrammatically.

The apparatus consists mainly of a frame of domite, A, of inverted U shape, the uprights, a^1 a^2, dipping into the water of the reservoir, B, and serving to convey the latter by capillarity up to the top, a.

This top part of the domite frame is in intimate contact with a convenient spongy substance, C, amadou for instance, which absorbs the water as it is drawn up by the domite uprights, a^1 a^2. This water is led by amadou filaments, c, to the paddles, D, of a wheel, E, conveniently balanced and mounted in front of the frame, A, so that the lower paddles never dip into the water of the tank, B. These paddles, D, which are always in free contact with the amadou filaments, c, are made of a spongy substance, blotting paper, domite, or the like, and receive the water, as has been stated above.

The paddles, D, are mounted in proximity to the amadou filaments, c, will be charged with moisture so as to destroy the equilibrium of the wheel, E, and to impart to the latter a rotary movement until the equilibrium is re-established. As, however, the water-saturated paddles are removed from the amadou filaments, c, the moisture contained in them will be vaporized, so that the equilibrium is once more destroyed, the upper paddles continually absorbing water from the filaments. The paddlewheel thus receives an intermittent movement of rotation, which may be utilized (as shown in the accompanying diagram) for raising water from the tank, B. For this purpose the shaft, e, of the wheel is fitted with a drum, F, or any other convenient attachment in connection with a chain of buckets, f, f^1, f^2.

The above principle can obviously be modified in many ways, using for instance instead of the reservoir the bed of a river or of a canal, substituting for the wheel a cross beam weighted on one side with a counterpoise, and bearing on the other one or several masses of spongeous matter.

The apparatus is interesting chiefly on account of the novel principle it embodies. It should be highly instructive in connection with practical demonstration, to show the effects of capillary attraction in school laboratories. Here, moreover, it may prove useful for the production of small amounts of motive power, and so really serve as a practical motor.

New Use for Old Boiler Tubes.

When visiting coal and metal mines, the writer has seen many piles of discarded boiler tubes. This is the case more often, where bad water is used in the boilers, and where the boilers have not had proper care in the way of cleaning; resulting in heavy deposits of scale, corroded and leaky tubes, which have to be cut out and replaced by new ones.

These old tubes or flues, when sold as scrap, bring so little that it hardly pays the cost of moving them; yet, a few dollars spent in cleaning them and attaching flanges, will make of them excellent air or water pipe which can be used where the pressure carried does not exceed 75 or 100 pounds per square inch. Wherever compressed air is used or water is to be pumped, the outlay for pipe is one of the large items of expense, and when used underground, only a small percentage of this pipe is returned to the surface in a serviceable condition.

A year or more ago a company had several hundred old boiler tubes mostly 3 inches, 3½ inches, and 4 inches in size and 16 to 18 feet long which were considered practically useless until experiment proved their value for pipe.

Threads and couplings cannot be used with success for joining the various lengths, for two reasons. First, the old tubes are usually too thin to allow for the threads, and secondly, they are apt to be out of a true circle. Flanging is therefore the best method for this purpose.—From article by D. E. Rust, in Mines and Minerals.

Another single-phase electric railway has been put into service in the United States. The Bloomington, Pontiac, and Joliet Electric Railway, designed to run from Bloomington, Ill., to Joliet, Ill., through Pontiac and Dwight, Ill., has been put into operation on a length of about 10 miles from Pontiac. A trolley line voltage of 3,000 volts is used.